Ceramic Production in Shang Societies of Anyang

JAMES B. STOLTMAN, ZHICHUN JING, JIGEN TANG, AND GEORGE (RIP) RAPP

INTRODUCTION

Anyang is the modern city where two of the earliest urban settlement sites in China, Huanbei and Yinxu, are located (Fig. 1; Anyang Work Station 2003*a*, 2003*b*; Jing et al. 2004; Tang 2001; Tang et al. 2000; Thorp 2006 : 131–132). They are usually referred to as middle and late Shang capitals. The urban settlement at Yinxu began in the middle or end of the thirteenth century B.C., and ended in the middle of the eleventh century B.C.[1] Huanbei, a recently discovered walled urban settlement, slightly preceded Yinxu in age; it probably arose in the middle or end of the fourteenth century B.C. and lasted for less than one century.

This article reports the initial findings of petrographic analyses of ceramic artifacts recovered from Huanbei and Yinxu.[2] The main goals of this report are as follows: 1) determine what local resources were being exploited by ceramic producers in Shang society; 2) provide objective criteria for distinguishing local from imported ceramic products at Huanbei and Yinxu; and 3) explore the implications of these findings concerning ceramic production and exchange in efforts to understand more fully the working of Shang society (Underhill 2002).

In pursuit of these objectives, 61 thin sections of various ceramic artifacts and raw materials from Huanbei and Yinxu were analyzed via petrography. The artifacts for thin-sectioning were selected with the goal to provide samples that represented the full range of variation of the local Shang ceramic industries. Thus, a wide range of ceramic products were analyzed, including such a mundane item as a drainpipe, several specialized artifacts associated with bronze casting—crucibles, piece molds, and a funnel—as well as a variety of pottery containers. Three pottery vessels that were suspected of being exotic to Anyang were included in the study. Since all thin sections were analyzed "blind," i.e., with no knowledge of the samples' identities other than their thin section numbers, it was hoped that the inclusion of the latter samples would provide independent

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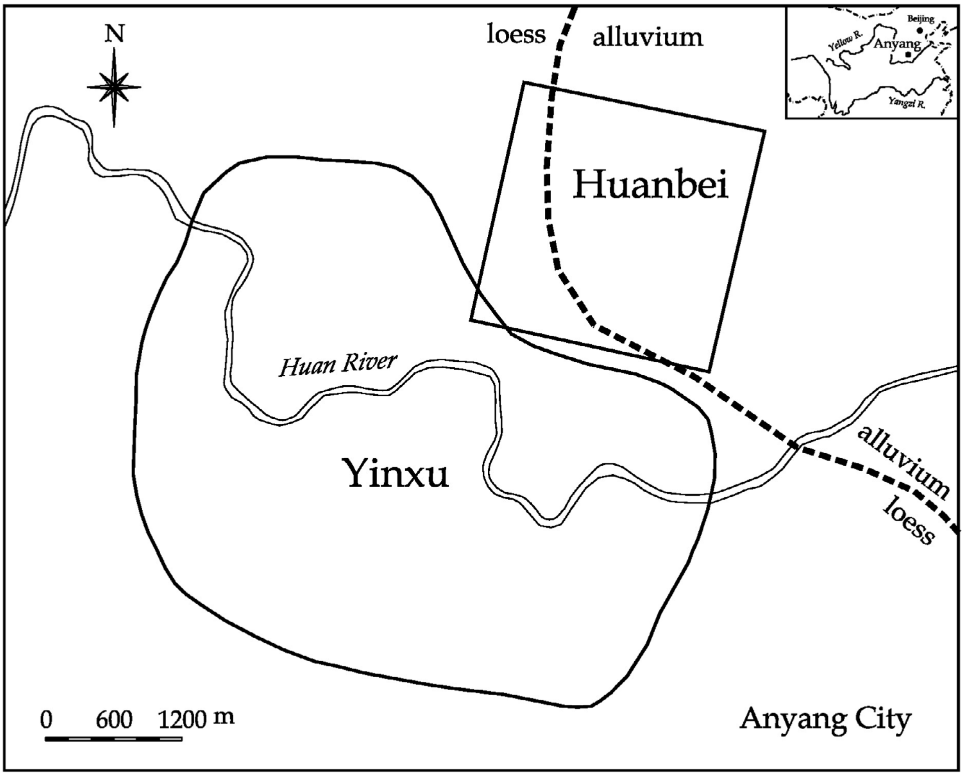


Fig. 1. Map showing the location of Huanbei and Yinxu. They are situated on the eastern edge of the Holocene loess, as indicated by the dashed line. The alluvium is found in the lower Huan River valley, east of Yinxu and Huanbei.

evidence for evaluating the effectiveness of the thin section analysis to discriminate local from non-local ceramic products at Anyang.

The vast majority of pottery recovered on Shang sites is gray ware (e.g., Cheng 1960 : 146; Institute of Archaeology 1994; Li 1977 : 202). Presumably most of this pottery was made locally for everyday use—Medley (1976 : 30) characterizes it as "pedestrian" and of "purely utilitarian function"—and is the focus of the present study. Also thin sectioned, but excluded from this study, were several vessels of white ware, stoneware/hardware (some glazed), and red ware. The former two are associated almost exclusively with elite contexts and generally regarded as imported luxury wares (e.g., Chang 1980 : 150–151; Chen et al. 1999; Institute of Archaeology 1994; Shangraw 1978 : 38–47; Thorp 2006 : 153–155; Vainker 1991 : 27–31; Yang 2003). Because the local status of the red ware is uncertain, its consideration will also be deferred until after a reliable local compositional baseline has been established from the gray ware analysis.

METHOD

The analytical approach used in this study is described in several publications (Stoltman 1989, 1991, 2001). Referred to as point counting, the approach is a sampling procedure involving observations made at 1-mm intervals across the entire area of each thin section. Excluding voids, in no case was the total point count less than 100, but in most cases over 200 points were counted per thin section. As a result of these observations, an estimate of the bulk composition of each thin section is obtained and presented quantitatively as the relative percentages of three mineralogical size grades—clay (or matrix) = <.002 mm; silt = .002–.0624 mm; and sand/gravel = .0625+ mm. For each of the sand-size grains encountered during the point counting (gravel grains—those >2.00 mm in maximum diameter—were rare), the mineral/rock types were identified and, based upon their measured maximum dimension, assigned a value within the following ordinal scale:

1 = Fine	.0625–.249 mm
2 = Medium	.25–.499 mm
3 = Coarse	.50–.99 mm
4 = Very coarse	1.00–1.99 mm
5 = Gravel	2.00+ mm

The individual grain size values were then summed and divided by the total number of sand and gravel grains counted, thus providing a mean "sand-size index," ranging between 1 and 5, for each thin section.

Based upon the mineral inclusions observed during thin section analysis, the ceramic artifacts in this study were assigned to two basic classes: temperless and tempered. The latter in turn was further divided into three subclasses, sand tempered, grit tempered, and grog tempered, with the last two not previously recognized in Shang ceramics. The ensuing discussion of these data begins with a comparison of the temperless artifacts to local, clay-rich sediments (Table 1; Fig. 2) in order to determine the compositional properties of locally produced ceramic artifacts. The rationale for this approach is that those artifacts lacking readily identifiable temper most probably were made from unaltered local materials.

By contrast, a direct comparison of the bulk compositions of natural sediments and tempered ceramic artifacts cannot yield meaningful results because the latter,

Table 1. Bulk Composition of Sediments and Temperless Gray-Ware Artifacts from Anyang

SEDIMENT/CERAMIC TYPES	N	%MATRIX	%SILT	%SAND	SAND SIZE INDEX
Local Sediments [n = 3]					
Alluvium	2	87.0 ± 1.4	11.5 ± 0.7	1.5 ± 0.7	1.44 ± .33
Loess	1	77	22	1	1.00
Temperless Non-Containers [n = 7]					
Yinxu Drain & Crucibles	3	78.7 ± 4.5	18.7 ± 2.1	2.6 ± 2.5	1.38 ± .12
Yinxu Bronze Molds	4	64.0 ± 5.0	34.0 ± 5.0	2.0 ± 0	1.00 ± 0
Temperless Vessels [n = 29]					
Huanbei	12	80.4 ± 2.2	16.8 ± 2.5	2.8 ± 1.5	1.31 ± .48
Huanbei Exotics (?)	4	89.0 ± 1.4	5.8 ± 1.5	5.2 ± 2.8	1.37 ± .10
Yinxu	13	79.2 ± 3.6	19.5 ± 3.5	1.4 ± 1.2	1.00 ± 0
Total	39				

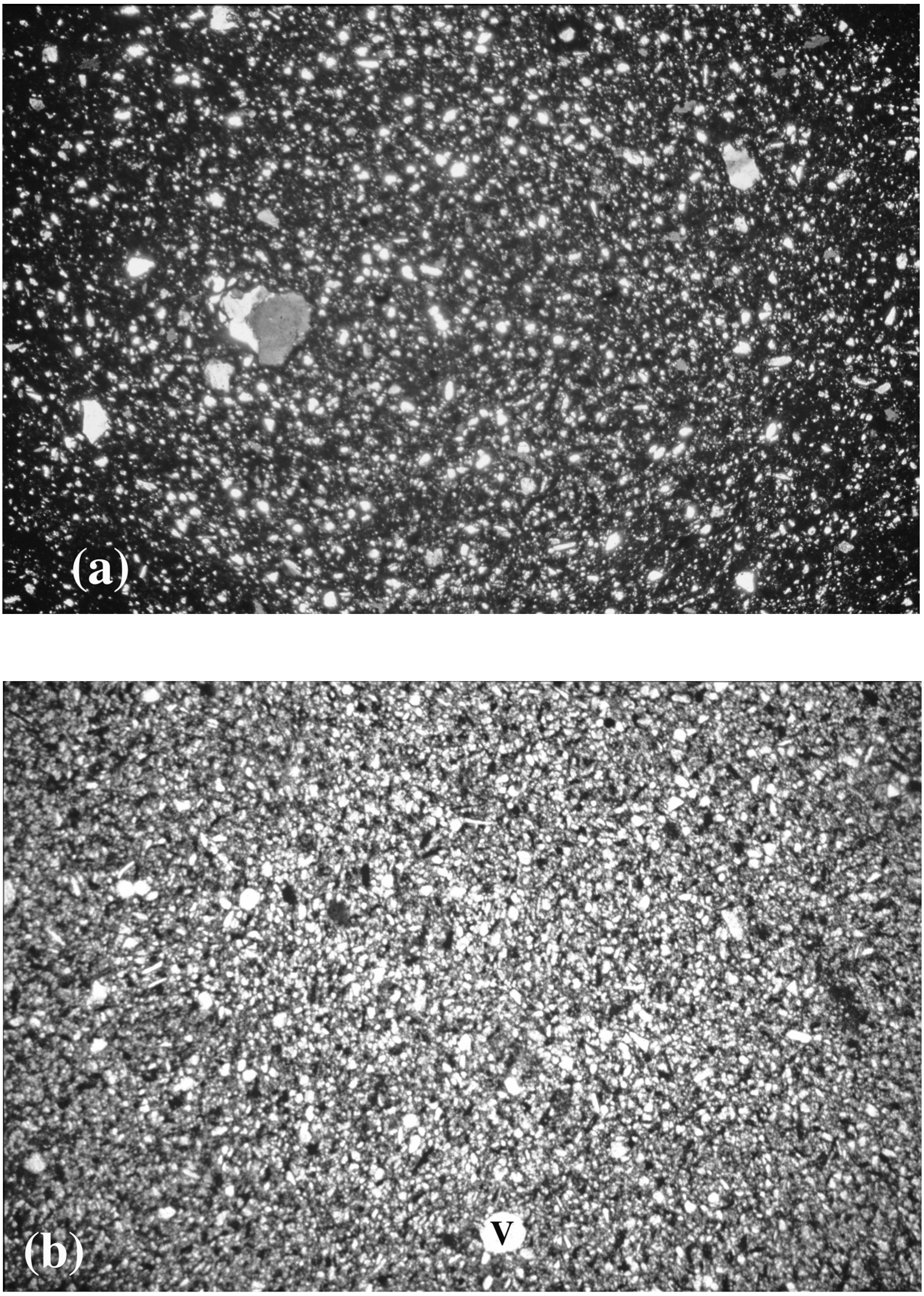


Fig. 2. Photomicrographs, both at 10X magnification, of local sediments from the Anyang locality: (a) = alluvium (viewed under crossed polars), (b) = loess (viewed under plane polars). Most of the white dots are quartz grains in the silt size range: (a) has 12% silt; (b) has 22% silt. Note several sand-size grains in the alluvium versus almost none in the loess. For scale, the large polycrystalline quartz grain in (a) measures .35 mm and the void (V) in (b) measures .175 mm.

unlike the former, is an artificial mixture for which no natural occurrences can be expected. It is possible, however, to mitigate this problem by adopting some additional procedures, depending upon the nature of tempers observed during the microscopic analysis.

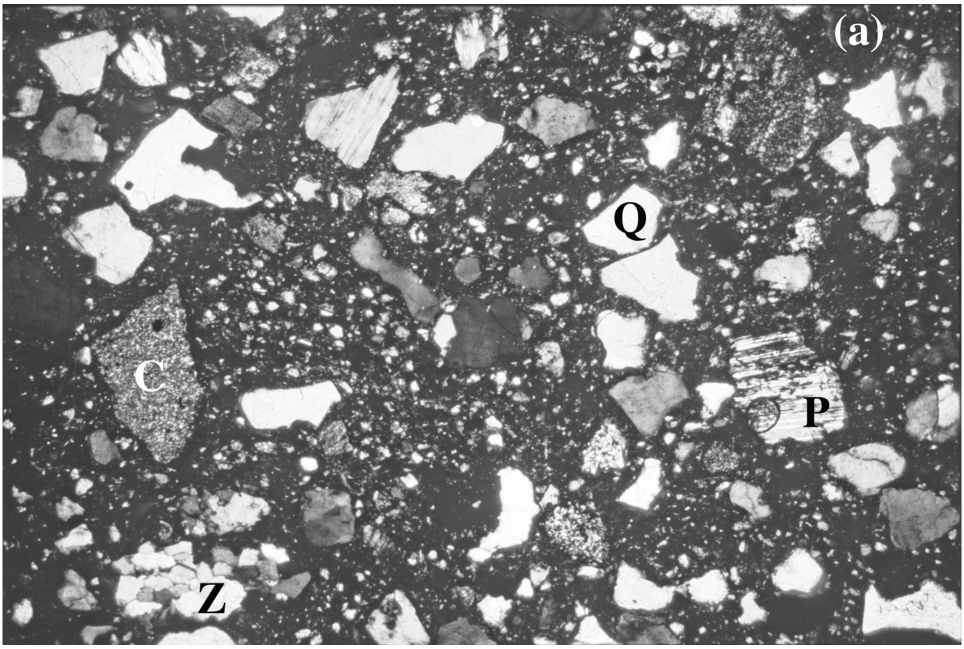
Those vessels identified as having sand temper are the most problematic. These artifacts are distinctive in possessing relatively high frequencies (i.e., >14%) of sand-size inclusions that are either preponderantly monomineralic (mainly quartz) or lithologically diverse (Fig. 3a). In addition they have relatively large sand-size indices, normally >1.50. The problem with this class revolves around difficulties in discriminating objectively between the alternative possibilities that the sands were natural inclusions or human additives. Comparisons with natural sediments will help in making this discrimination, but, nonetheless, the term "sand tempered" should be viewed as a descriptive expedient rather than a definitive conclusion.

In contrast to temperless and sand-tempered artifacts, grit-tempered artifacts possess abundant coarse, angular fragments of polymineralic igneous rocks of granitic composition (Fig. 3b) as that term is defined in Le Maitre (2002:29). The principal mineral constituents are polycrystalline quartz accompanied by varying combinations of microcline and plagioclase, all of which show considerable evidence of alteration. The sand-size indices for these artifacts exceed 2.00 (Table 2). There is no doubt that such rocks are exotic to the North China plain. Whether the artifacts or the rocks were imported is debatable, an issue that will be addressed further below. For this artifact class, unlike the others, it is possible to identify the human additives reliably, and thus to remove them from the bulk composition in order to estimate the composition of the original sediments, i.e., the paste, from which they were made (see Stoltman 1991:109–110, 2001:304). This is also the case for the one grog-tempered vessel.

It is presently unknown how reliably the current 61-thin-section sample can be viewed as representative of the ceramic industries at Anyang. Thus, this study is offered as both a tentative and preliminary effort to characterize the ceramic production practices of local Shang potters.

COMPOSITION OF LOCAL SEDIMENTS

Before considering the compositions of ceramic artifacts, the character of local clay-rich sediments suitable for the manufacture of such artifacts is first discussed. Anyang lies within the North China plain, a region "covered by vast deposits of loess in both its wind-blown and water-deposited forms" (Kerr and Wood 2004:90). These loess deposits are of Pleistocene and Holocene age. Anyang is situated near the eastern margin of the Holocene loess (Fig. 1). Samples were collected from undisturbed, buried sediments encountered at various times and places during the course of archaeological research in and around Anyang. Care was taken that these sediments predated the Shang period so as to ensure their potential availability to Shang potters.[3] Thin sections for samples that expressed the greatest visible range of sediment variation were prepared and analyzed in the same manner as the pottery thin sections. The bulk compositions of three such sediments are recorded in Table 1.



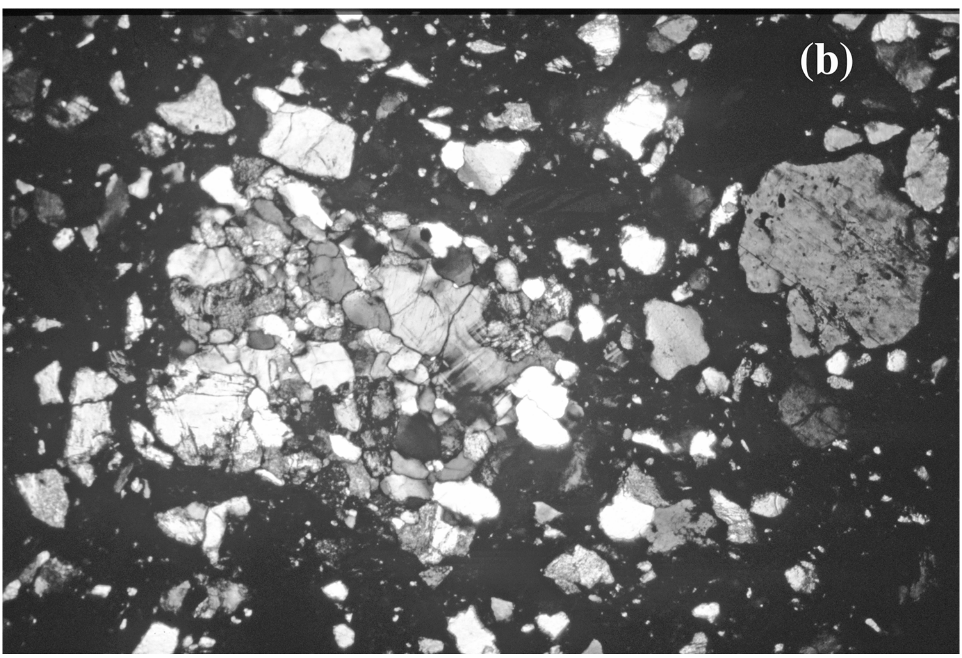


Fig. 3. Photomicrographs, both at 10X magnification, of two tempered vessels: (a) with sand temper; (b) with grit temper. Note the mineralogical diversity in (a), with Z = quartzite, C = chert, P = plagioclase, and Q = quartz. Scale: the quartzite (Z) grain in (a) measures .75 mm and the large, polymineralic, granitic grain in (b) measures 1.70 mm. Note the lesser amounts of silt in these vessels—7% in (a) and 5% in (b)—in contrast to the sediments in Figure 2.

Table 2. Bulk Composition of Tempered Gray-Ware Ceramics from Anyang

CERAMIC TYPES	N	%MATRIX	%SILT	%SAND	SAND SIZE INDEX
Sand Tempered [n = 16]					
Huanbei vessels [10 *li*]	10	65.4 ± 4.9	10.2 ± 5.5	24.4 ± 8.0	1.65 ± .26
Yinxu vessels [4 *li*, 1 *yan*, 1 *guan*]	6	68.0 ± 9.3	7.2 ± 3.1	24.8 ± 8.2	1.92 ± .56
Grit Tempered [n = 5]					
Huanbei *li*	1	81	2	17	2.04
Yinxu vessels [2 *li*, 1 *guan*]	3	65.0 ± 12.5	8.7 ± 5.1	26.3 ± 17.6	2.69 ± .56
Yinxu Funnel	1	80	6	14	2.88
Grog Tempered [n = 1]					
Yinxu *li*	1	77	12	11	3.29
Total	22				

Local alluvial and aeolian sediments were both sampled and, as can be seen from Table 1, the loess is notably siltier—22 percent vs. 11.5 percent—than the alluvium. While the incidence of sand is minor in both types, sand grains in the medium and coarse size grades are present in the alluvium whereas virtually all sands in the loess are in the fine size grade. These data give quantitative expression to the compositional differences that typify local alluvial (Fig. 2a) as opposed to aeolian deposits (Fig. 2b).

TEMPERLESS ARTIFACTS

Temperless Pottery Vessels

Over half of the gray-ware pottery vessels analyzed in this study—29 of 50—lack visible temper. They are composed preponderantly of clay and silt with only minor amounts of sand—a maximum of 8 percent. Moreover, the sand grains present are mostly fine, only a few are medium, with the resultant sand-size indices averaging less than 1.40 (Table 1). Earthenware is an apt characterization of these vessels because their bodies are generally porous, although vitrification was observed to have begun in a few instances. Sixteen of these vessels are from Huanbei, while 13 are from Yinxu (Table 1). From Figures 4 and 5, it can be seen that at least 8 of these 29 vessels—7 from Yinxu and 1 from Huanbei—seem clearly to have been made from loess (i.e., have >20% silt). Five others (with <15% silt)—all from Huanbei—were apparently made from alluvium (Fig. 5). The remaining 16 vessels have intermediate silt values, ranging between 15 percent and 19 percent (Figs. 4 and 5). It seems reasonable to view these vessels as derived from altered loessic sediments, which henceforth shall be referred to as "reworked loess." This term may eventually prove to be inaccurate or in need of redefinition in light of an expanded database, but for the present, at least, it serves as a convenient designator for sediments with relatively high silt values intermediate between those of the local alluvium and loess.

Beside the relative paucity of temperless vessels made from alluvium, additional evidence suggests that at least four of the five may be of nonlocal origin. These four have uniquely low silt values (7% or less) that can be viewed as placing them beyond the range of variation of the local alluvium (see Fig. 5 and Table 1).

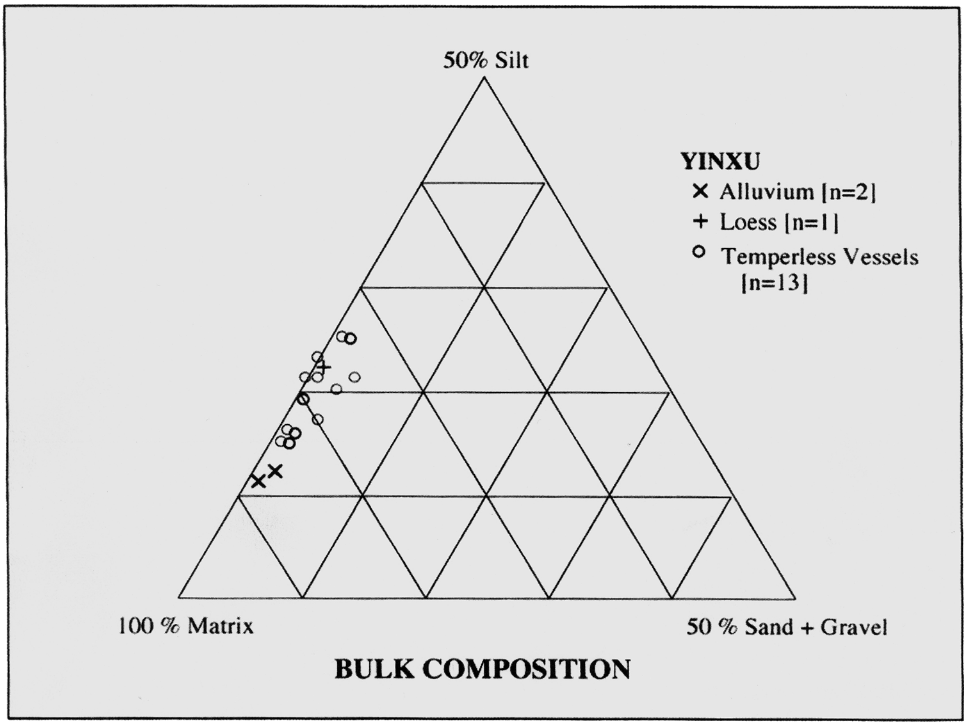


Fig. 4. Ternary plot showing bulk compositions of temperless pottery vessels from Yinxu versus local sediments.

Further support for this view occurs in that two of these vessels—the two with the lowest silt content (4% and 5%)—were among the three vessels singled out by Jigen Tang as stylistically anomalous, i.e., probably of nonlocal origin. Similarly, the other two low-silt vessels have unique properties suggestive of nonlocal origins: one has a black-slipped surface with a distinctive calcareous paste, while the other has an unusually high incidence of amphiboles. These four potentially exotic vessels are denoted by dotted circles in Figure 5. While the exotic origin of the low-silt vessels can be debated, at the very least, the current data demonstrate a decided preference by Shang potters for loessic sediments when making untempered pottery vessels.

Employing traditional Chinese terms for vessel forms, the 29 temperless vessels are represented by the following: 4 *guan*, 5 *rentouguan*, 5 *pen*, 2 *dou*, 2 *zun*, 3 *gu*, 1 *jia*, 1 *gui*, 2 *jue*, 2 *zeng*, and 2 *li* (e.g., Chang 1980; Cheng 1960: 149; Thorp 1985: 30, 2006: 38). The two *zun*, one *gu*, and one *pen* are the suspected exotics.

In sum, if the current sample is not biased, potters at Huanbei and Yinxu apparently made the majority of their products from local loessic sediments that were prepared and fired successfully without the addition of temper. Lesser numbers of vessels were made from untempered alluvial sediments, but several of these are probable imports. These temperless vessels occurred in various forms that served a variety of functions, such as transport, serving, and storage, but, with the

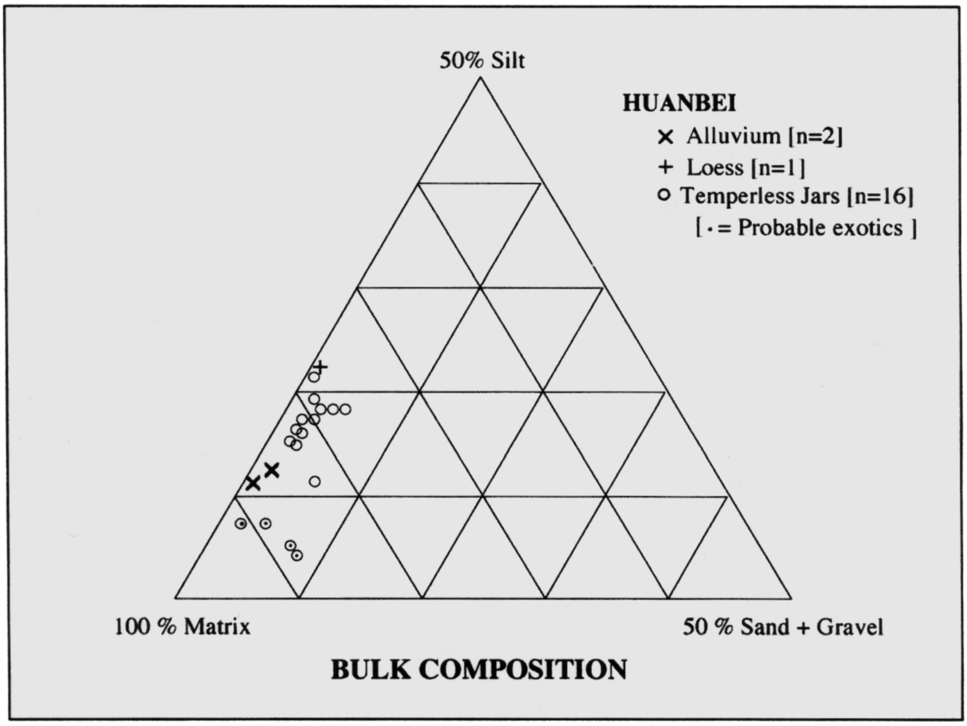


Fig. 5. Ternary plot showing bulk compositions of temperless pottery vessels from Huanbei versus local sediments.

exception of the two *li* tripods (cooking vessels) and the two *zeng* (steamer bowls), none was apparently employed in ways involving direct contact with fire during their use lives.

Temperless Ceramic Artifacts Other Than Pottery Vessels

Eight ceramic artifacts other than pottery containers, all from Yinxu, were included in this study for two reasons: 1) to provide data to supplement the sediment samples concerning the composition of local, clay-rich sediments under the supposition that they can be regarded as local products with reasonable certainty; and 2) to provide a broader characterization of Shang ceramic making than could be gained from the analysis of pottery containers alone. The eight artifacts involved include a cylindrical drainpipe (e.g., Kerr and Wood 2004:106–107), four bronze piece molds, two probable crucibles, and one funnel used in bronze production. The funnel proved to be distinctive. It has an igneous rock temper and will be considered with the other grit-tempered artifacts below. The remaining seven artifacts all lack visible temper and are generally characterized by high silt values that range from 17 percent to 39 percent. By referring to Figure 6, where the bulk compositions are plotted individually for each of these artifacts versus the local sediments, it is evident that the Shang craftpersons of Anyang

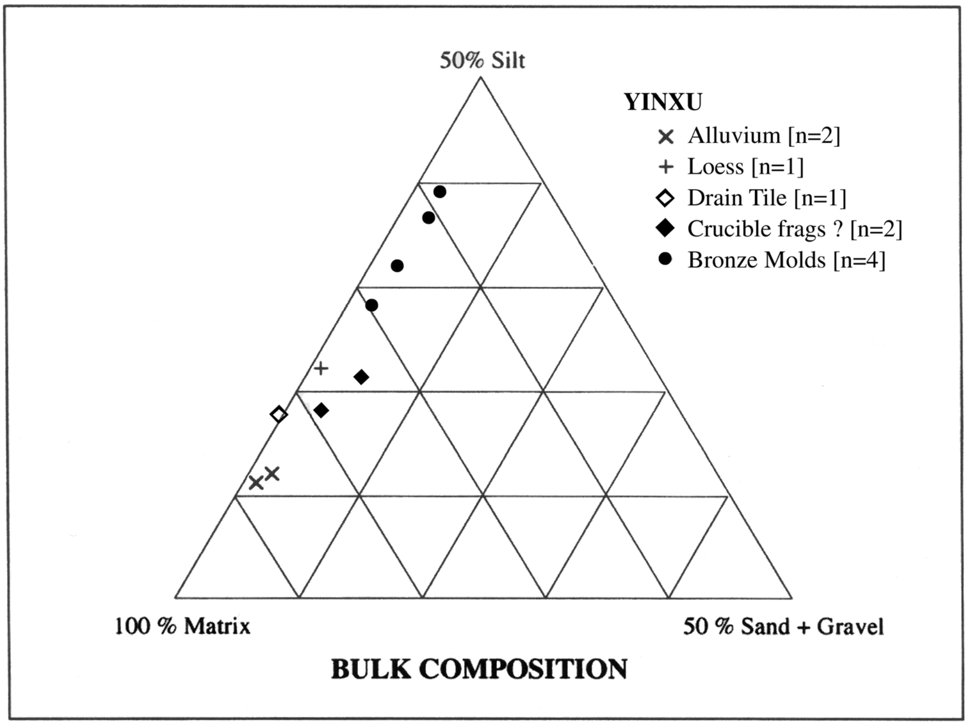


Fig. 6. Ternary plot showing bulk compositions of sediments and untempered ceramic artifacts from Yinxu other than pottery vessels.

resorted primarily to the local loessic sediments when making ceramic objects other than pottery vessels.

The four bronze molds are distinctive in possessing the highest silt values of any artifacts in this study (Table 1 and Fig. 6). According to Kerr and Wood (2004:103), "The particular virtues of fired loess as a bronze-casting mould-material are its fine particle-size range, combined with high porosity." These properties would facilitate the escape of gases through the porous mold when the molten bronze was added, thus preventing flaws to form in the cast objects (ibid.) while simultaneously providing highly uniform surfaces onto which the intricate decorative motifs could be clearly rendered. The data in Figure 6 suggest that it was not simply loess, but refined loess that was used in bronze mold manufacture. This view is consistent with the suggestion of Kerr and Wood (2004:103) that rather than careful selection of raw materials, the mold makers deliberately washed away some of the clay "by stirring up the loess with an excess of water and pouring off the top layer that stayed in suspension." The result of such processing would be precisely that observed in Figure 6, a relative elevation in silt values in contrast to other artifacts made from loess.

Another presumed virtue of such materials for bronze molds would be their low amount of shrinkage because expansion would be absorbed in the pore spaces within the molds without a change in size or shape (ibid.). Thus, as Vainker

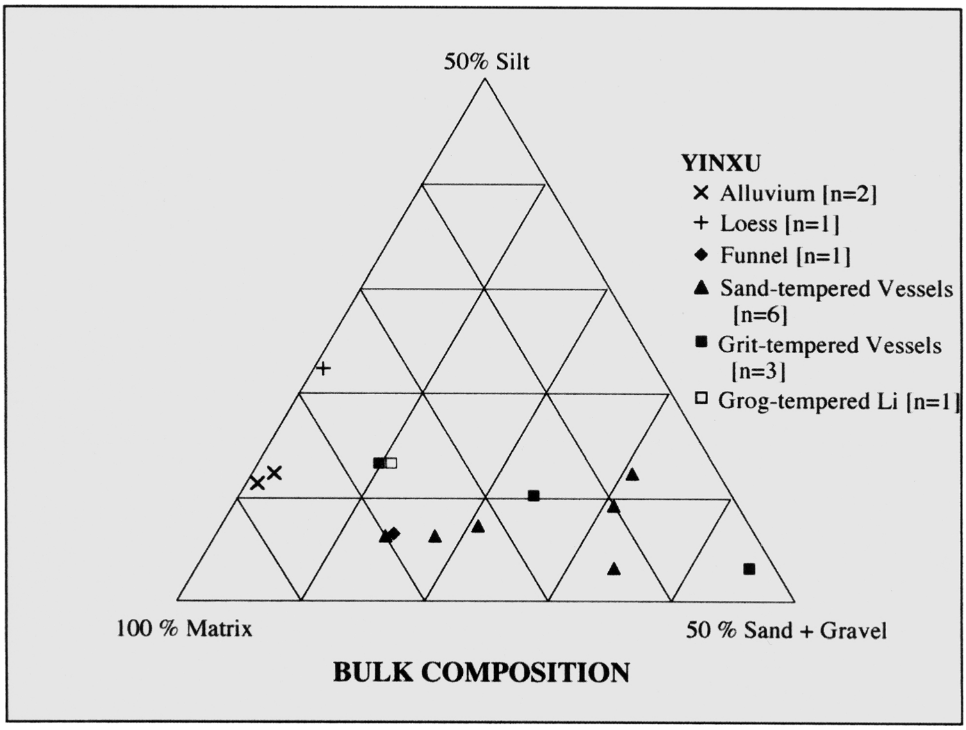


Fig. 7. Ternary plot showing bulk compositions of tempered ceramic artifacts from Yinxu versus local sediments.

(1991:27) suggests, it was the low-shrinkage properties of the bronze molds that permitted the survival of the intricate decoration they imparted onto the finished Yinxu bronzes. While the current sample is small, it is reasonable to view the distinctive composition of these four mold fragments as indicative of the high degree of sophistication and specialization associated with the manufacture of bronze piece molds, which Kerr and Wood (2004:104) rightly describe as "disposable masterpieces of ceramic design and engineering."

TEMPERED CERAMIC ARTIFACTS

Sand-Tempered Pottery Vessels

Sixteen of the thin-sectioned gray-ware vessels were identified as sand tempered (Table 2). Whether the sands were added intentionally or were natural inclusions in sandy sediments, there is little doubt that the distinctive composition of these vessels reflects conscious decision making on the part of the potters (see Figs. 7 and 8).

As can be seen from Table 2, the sand content of these vessels averages over 24 percent, far greater than the 8 percent maximum recorded for any of the temperless vessels. In addition, the mean sand-size indices of 1.65 and 1.92 for Huanbei and Yinxu are significantly higher than those for the temperless vessels from the

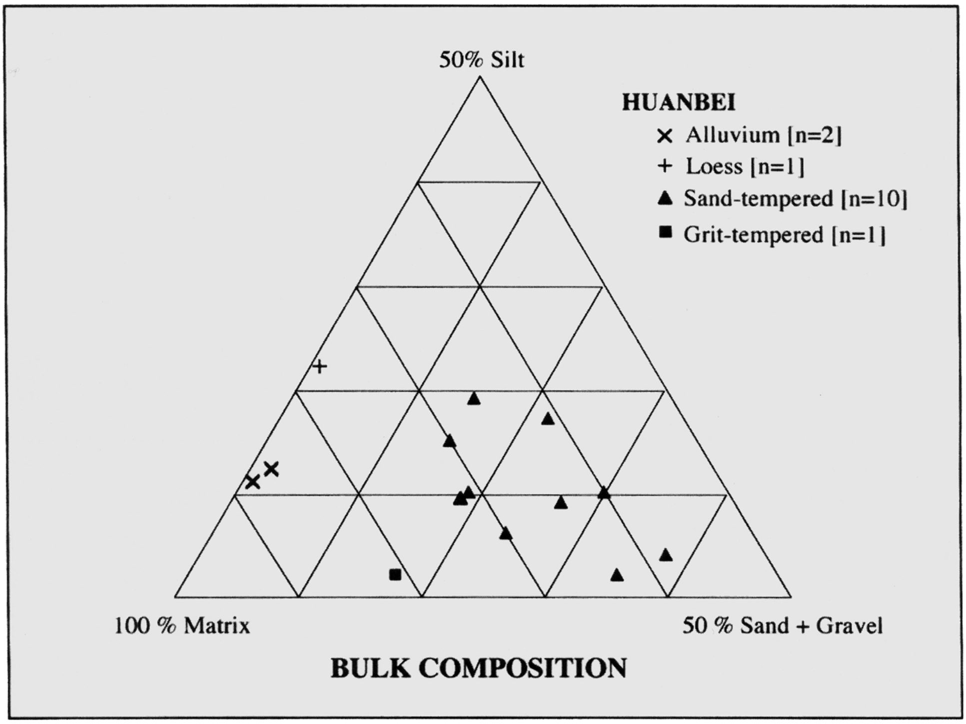


Fig. 8. Ternary plot showing bulk compositions of tempered pottery vessels from Huanbei versus local sediments.

same sites (Table 1), reflecting the fact that sand grains in the medium and coarse size ranges typically constitute half or more of the sand fraction.

In one sense the term sand tempered is purely textural, applying to mineral grains of any composition with maximum dimensions of .0625 mm and larger. Somewhat more is implied, however, because sand-tempered vessels must also be distinguished from grit-tempered vessels that are equally coarse grained. Thus, sand tempering here is identified not only by the relatively high incidence (i.e., >14% of bulk composition) of sand-size particles but by the presence of sand grains that are either predominantly monomineralic or of diverse composition when they are not preponderantly quartz (see Fig. 3a). The specific properties of grit-tempered vessels will be considered further below.

Accepting, for the sake of argument, that most of the medium and coarse sand grains, along with some of the fine sand grains, were intentionally added as temper, the composition of the original "raw" clays (i.e., *paste*) can be estimated by subtracting the added sand grains and recalculating the bulk compositions. But how does one determine which sand grains were added as opposed to natural? This problem can be addressed by adopting a simple expedient: accepting 2 percent sand—the average amount in the three local sediments as well as the mean sand content of the 32 temperless artifacts (excluding the four possibly nonlocal vessels from Huanbei)—as a reasonable estimate of the amount of natural sand

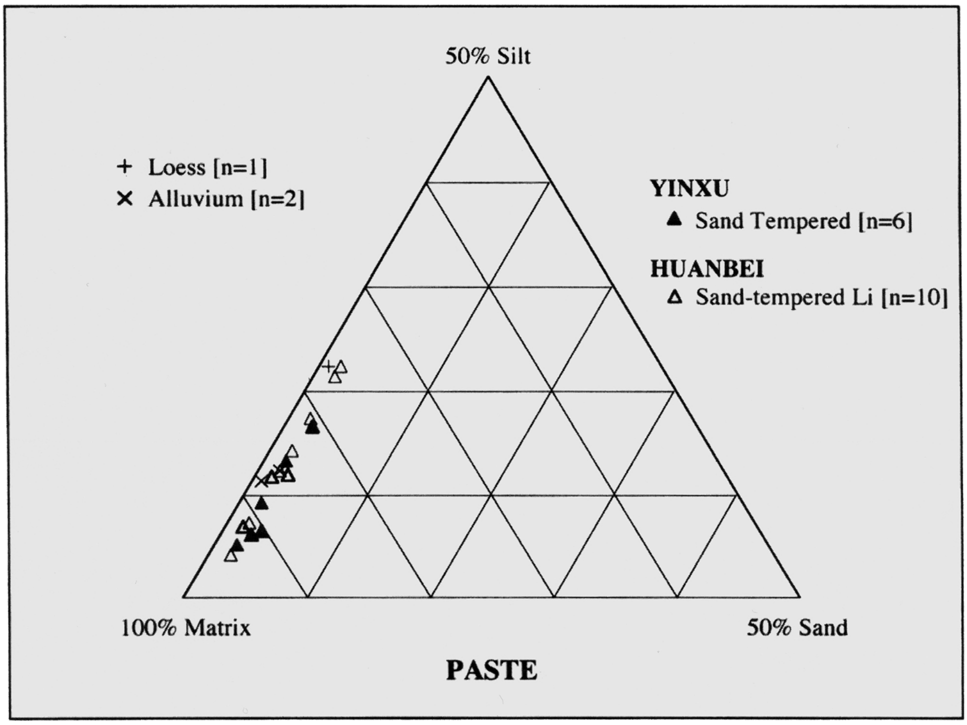


Fig. 9. Ternary plot showing paste compositions of sand-tempered vessels from Yinxu and Huanbei versus local sediments.

originally present in local sediments (see Table 1). Accepting 2 percent as the "normal" amount of natural sand in local sediments, the measured sand content for each of the 16 vessels classed as sand tempered was progressively reduced and the bulk compositions recomputed until the 2 percent sand level was attained. The result of this process—the conversion of bulk compositions to paste compositions—is presented in Figure 9 for the 16 sand-tempered, gray-ware vessels.

As a result of this process, 12 of the 16 sand-tempered vessels were determined to have been manufactured from alluvium, i.e., to possess less than 15 percent silt in their pastes. By contrast, only two of the 16 sand-tempered vessels have paste values in excess of 20 percent silt (i.e., were made from loess). The remaining two sand-tempered vessels, both with pastes characterized by 17 percent silt, apparently were made from reworked loess. The apparent strong association between alluvial sediments and sand temper stands in marked contrast to the prevalence of loessic sediments associated with the temperless artifacts.

Six of the sand-tempered vessels (three each from Yinxu and Huanbei; see Fig. 9) have low silt values in their pastes (i.e., 8% or less). Once again a vessel identified as nonlocal on stylistic grounds (a *li* tripod from Yinxu in this case) had a low-silt, alluvial paste. Considering the paucity of such low silt values noted previously among the temperless vessels (cf. Figs. 4 and 5), the possibility of the nonlocal origin of these six low-silt, sand-tempered vessels deserves serious consideration.

Why were some vessels untempered and others sand tempered? If the latter vessels were imported, the observed differences could be simply regional, i.e., due to between-community differences in pottery-making practices or materials. An alternative, but not mutually exclusive, explanation, however, is that these differences reflect the potters' intent to enhance the performance properties of vessels designed for specific functions. Of particular relevance in this regard is the fact that 14 of the sand-tempered vessels are *li* tripods and 1 is a steamer (*yan*), i.e., 15 of the 16 sand-tempered, gray-ware vessels are of types primarily used for cooking (e.g., Cheng 1960 : 148–150).[4] It is reasonable to postulate that it was to minimize the negative effects of thermal stress (especially crack propagation) that prompted the potters to add sand to these vessels (e.g., Bronitsky and Hamer 1986; Rye 1976; Steponaitis 1984).

Grit-Tempered Artifacts

The most surprising discovery of this study was the recognition that crushed fragments of medium-grained granitic rock had been added as temper to several vessels as well as to the funnel. Four of the gray-ware vessels, three *li* tripods and one *guan*, were observed to have such temper (Table 2; Fig. 3b). One *li* from Yinxu is unique in possessing limestone along with the granitic temper.

Beside their polymineralic character, the inclusions in these vessels are distinguished by their relatively large size and high angularity (Fig. 3b). The mean size index for the grit temper (excluding natural sand grains) in these five artifacts is $2.70 \pm .40$, considerably larger even than the sands in the sand-tempered vessels.

As with the sand-tempered vessels, most of the grit-tempered vessels (three of four) are *li* tripods. Thus, along with the funnel from Yinxu, four of the five grit-tempered, gray-ware artifacts in the present sample were apparently intended to survive intense heat (the funnel from molten metal) during their use lives. From this, it is reasonable to infer that it was the intended function of these vessels that motivated the potters to employ such compositional recipes in their manufacture.

While the rocks used as temper are definitely exotic to Anyang (no such rocks outcrop closer than the Taihang Mountains 20 km to the west), a difficult question remains: were the rocks imported for use as temper, or were the finished vessels imported? A consideration of the paste compositions of these vessels can be used to address this question under the supposition that the pastes, too, should be nonlocal in character if the vessels were manufactured elsewhere.

When the tempers are deleted from the bulk compositions so as to determine the paste values for these five artifacts, the results indicate that all were made from alluvium, none from loess. From Figure 10, it can be seen that two of the grit-tempered vessels have paste values of 13–14 percent silt and 1 percent sand, consistent with the values for local alluvial sediments. The remaining two vessels and the funnel have silt values from 3–7 percent, with unusually high sand values of 5–7 percent for the two vessels, all of which is suggestive (along with the exotic temper itself) of nonlocal origins for at least three of these artifacts.

Grog-Tempered Vessel

One gray-ware *li* tripod from Yinxu was tempered with grog, i.e., crushed pottery (Fig. 11). Its bulk composition is similar to that of other *li* tripods in

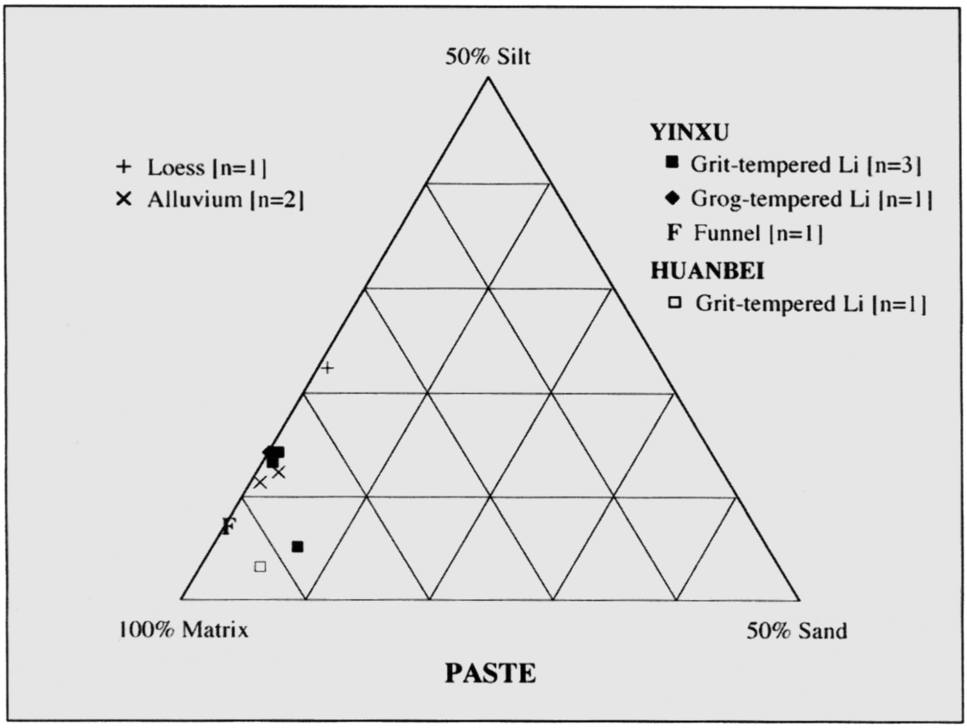


Fig. 10. Ternary plot showing paste compositions of grit- and grog-tempered artifacts from Yinxu and Huanbei versus local sediments.

possessing >10 percent sand-size inclusions (Table 2). It can be seen from Table 2 that the sand-size index for the bulk composition of this vessel (which includes the grog) is significantly higher than for any of the other vessels. This is due to the coarseness of the grog, which alone has an average size index of 3.47.

From Figure 10, it can be seen that the grog-tempered vessel has a paste with a composition similar to that of local alluvial sediments. By contrast, the composition of the grog temper is markedly different from both the local alluvium and loess. As shown in Figure 11, the grog is extraordinarily fine in texture, with both silt and sand rare. It is unlikely that such a paste was derived from local sediments unless they had been extensively refined. The local manufacture of this vessel thus cannot be ruled out, but the combined uniqueness of the grog and its distinctive composition are suggestive of a nonlocal derivation.

CONCLUSIONS

While the stylistic analysis of pottery is indispensable for placing archaeological sites in proper cultural/temporal contexts within the framework of a regional research program, knowledge of pottery composition has the potential to provide much additional, valuable information about human relationships to the landscape. Through the petrographic analysis of thin sections of sediments and

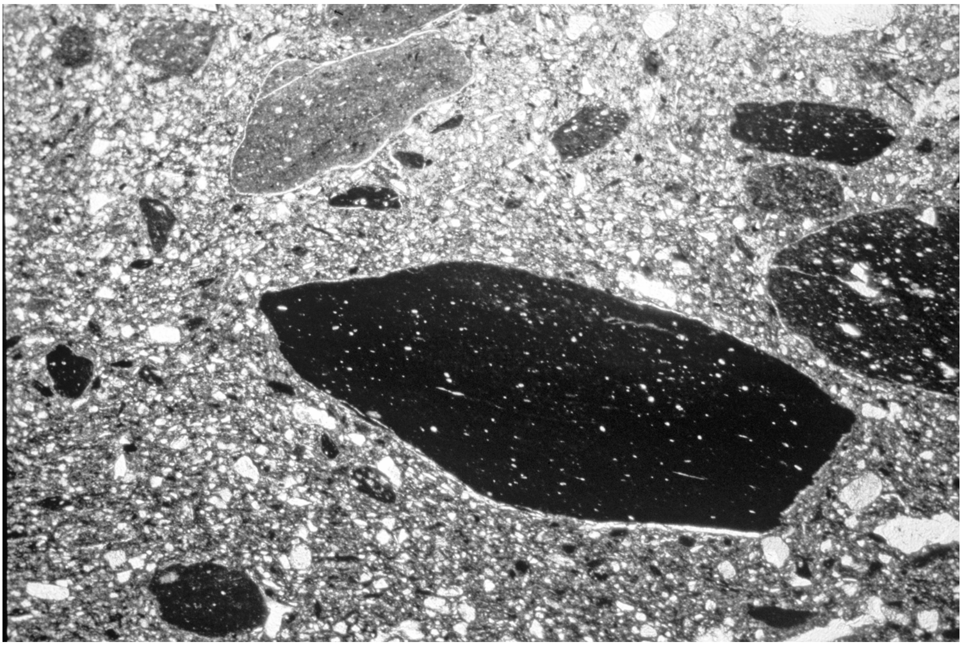


Fig. 11. Photomicrograph of the grog-tempered li from Yinxu. Photographed at 10X magnification. Largest grog = 2.40 mm. Silt content of vessel paste = 14%.

ceramic artifacts, the main goal of this study was initially to determine the composition of locally made ceramics to serve as a baseline for subsequent investigations of pottery production and exchange. The focus, then, was upon gray wares, the most common ceramics at Shang sites (e.g., Cheng 1960:146–148; Shangraw 1978:40–43; Thorp 2006:153–155). Sixty-one samples were thin-sectioned, including 3 local sediments, 8 ceramic artifacts other than pottery containers, and 50 pottery vessels.

Perhaps the most important finding of this study is the evidence uncovered for the complexity and multidimensional character of Shang ceramic industries at Huanbei and Yinxu. This evidence demonstrates that the Shang ceramists were highly skilled and sophisticated technicians who utilized a wide range of raw materials, some possibly imported, which were prepared, mixed, and/or modified in various ways depending upon the intended functions of the fired products. A fuller understanding of Shang ceramic production at Anyang awaits the discovery of kilns and other pottery making facilities, something that has eluded archaeologists despite over a half century of extensive excavation.

This study has documented the existence of considerable compositional diversity within Shang ceramics, diversity that cannot be accounted for simply by appealing to random resource variation or extensive external trade. The quantitative analyses employed in this study suggest that Shang artisans utilized at least three local sediment types, along with a fourth that appears to be exotic. These sediment types are defined as follows:

1. Loess: >20% silt; usually no more than 1% sand; sand-size indices rarely >1.00
2. Reworked loess: 15–19% silt; >1% sand; sand-size indices >1.25
3. Local alluvium: 9–14% silt; >1% sand; sand-size indices usually >1.25
4. Nonlocal alluvium: <9% silt; >2% sand; sand-size indices >1.25.

These sediment types were defined on the basis of a comparative analysis of the compositions of local sediments and a series of untempered artifacts that were almost certainly made directly from local sediments. Reference to these sediment types, which are directly comparable to ceramic pastes, permits several useful inferences to be made, but their limitations should not be overlooked. For example, the term, reworked loess, is offered tentatively for a sediment type that seems real enough (see Figs. 4 and 5), but whose origins and presence "in the ground" remain to be confirmed. Also, the absence, so far, of low-silt alluvium in the Anyang vicinity may be an artifact of sampling, so the characterization of this sediment as nonlocal should be accepted with caution. Recognition of these local sediment types has been used, albeit tentatively, to assist in identifying imported ceramic artifacts, but they promise to be most effective when used not in isolation but in conjunction with other lines of independent evidence, such as stylistic properties and types of temper.

In utilizing these local resources for the manufacture of ceramic items, Shang artisans in the Anyang region employed three basic technologies, each directed toward a different end: 1) the manufacture of a wide range of temperless artifacts; 2) the production of a more limited range of tempered vessels designed to withstand heat stresses; and 3) the manufacture of bronze piece molds (so far documented only at Yinxu). While yet to be confirmed in the archaeological record (neither kilns nor pottery workshops have been documented for the two Shang sites at Anyang), these three technologies are so distinct that it is reasonable to suggest that the third, and possibly also the second, were the work of specialized artisans in discrete workshops. In addition, several vessels were likely imported from outside Anyang.

The first technology, which involved the direct use of untempered sediments, is represented in 32 of the 58 artifacts thin-sectioned for this study. Included among the 32 untempered artifacts are a drainpipe and two crucibles along with 29 pottery vessels (Table 1). The latter are represented by a great variety of forms, the vast majority of which—25 of 29—were designed for such tasks as transport, storage, and serving that required limited or no contact with fire. The exceptions to the latter generalization include two *li* tripods from Yinxu and two steamers, one each from Yinxu and Huanbei. For the majority of pottery containers made with this technology—24 of 29—the sediment of choice was loess or reworked loess (see Figs. 4 and 5). Only five of the untempered vessels were made from alluvium, and four of those are suspected to be of nonlocal origin on independent grounds along with their low-silt pastes (Fig. 5). Thus, the use of untempered loessic sediments appears to be the prevalent technology for the production of a wide range of ceramic artifacts used in everyday activities in Shang society. If any pottery production in Shang society was conducted by non-specialists, it would most likely have involved vessels made with this technology since it was the simplest and made use of readily available local materials.

In contrast to the majority of untempered vessels, five were made from alluvium, i.e., have <15 percent silt (Fig. 5). Four of these vessels, all from Huanbei (Fig. 5), are suspected of being imports on stylistic and mineralogical grounds independent of their bulk compositions. Since these vessels also have the lowest silt values (i.e., 7% or less) among the 29 temperless vessels, they are especially strong candidates for consideration as nonlocal products and, by implication, so are other vessels with such low silt values.

The second technology, which involved the intentional addition of aplastic inclusions to the paste in forming vessel bodies, is closely associated with the manufacture of ceramic artifacts that were subjected to recurrent heating and cooling during their use lives. Twenty-two such artifacts were identified in this study (Table 2). The majority, 18, are *li* tripods variously tempered with sand (n = 14), grit (n = 3), and grog (n = 1). The remaining tempered artifacts include one sand-tempered steamer (*yan*), the grit-tempered funnel, and two *guan*, one each with sand and grit tempers.

The bulk compositions of the tempered artifacts as presented in Figures 7 and 8 dramatize the starkness of the contrast in texture between them and the temperless artifacts (cf. Figs. 4–6). In view of the high incidence of containers subject to recurrent heating and cooling among the tempered artifacts (20 of the 22 including the funnel) and the paucity of *li* tripods (n = 2) and steamers (n = 2) among the 29 temperless vessels, it is reasonable to attribute the addition of temper to ceramic artifacts to functional considerations on the part of the Shang artisans.

While a comparison of the bulk compositions of the tempered and temperless artifacts is relevant to the issue of the uses toward which these artifacts were directed, such comparisons are problematic in dealing with the issue of source determination of raw materials. Once the presence of temper, i.e., a human additive, has been documented thus confirming the artificial nature of the bulk composition of such artifacts, comparisons with the compositions of natural sediments or untempered artifacts becomes an exercise in futility. By excluding the temper from the bodies of such artifacts, however, productive comparisons of the resultant pastes (see Stoltman 2001:304–305) with untempered sediments and artifacts become tenable. By thus converting the bulk composition values to paste values for the 22 tempered artifacts, it was possible to determine that the vast majority (n = 18) were made from alluvium (Figs. 9 and 10). The remaining four are divided equally between reworked loess and loess (Fig. 9). The preferential use of alluvial sediments in the manufacture of tempered artifacts thus appears to have been a robust practice among Shang artisans, one that is in stark contrast to the preferential use of loessic sediments when temperless artifacts were produced.

But, why were three different tempers used? One possibility is that some of these artifacts were imports to Anyang. This must certainly be considered a strong possibility for the grit-tempered artifacts and for the grog-tempered vessel. In the case of the five grit-tempered artifacts, the igneous rocks that characterize them do not outcrop within 20 km of Anyang. Interestingly, two of the grit-tempered vessels have pastes that are similar to the local alluvium (Fig. 10), suggesting that in at least some cases it was the temper rather than the finished artifact that was imported. By contrast, the other two grit-tempered vessels and the funnel have low-silt pastes consistent with the temperless-vessel evidence suggestive of nonlocal origins (cf. Figs. 5 and 10).

For the 16 sand-tempered vessels, the reconstructed paste evidence is so variable that multiple origins, both local and nonlocal, seem likely (Fig. 9). At least two of these vessels were made from loess, two from reworked loess, with six others composed of alluvium similar to that available locally. This leaves six vessels characterized by low-silt (i.e., 8% or less) alluvium that *could* be nonlocal in origin. Whether tempered pottery vessels were household crafts or products of specialized workshops is presently unknown.

The third technology was applied to an even more limited range of ceramic products, bronze piece molds (Tan 1999). They were obviously made from untempered loess, but differ from the temperless vessels in a most interesting way: they are much siltier (Fig. 6). It is possible that the high silt content of these objects is attributable to the careful selection of a distinctive raw material by the artisans. Because no such raw material has been documented in the Anyang locality, another alternative deserves serious consideration, "that the very finest fractions were deliberately washed away during the material's processing" (Kerr and Wood 2004 : 103). The high silt values recorded for the four bronze molds in this study are consistent with this view, and serve to underscore the high degree of sophistication and specialization that characterized the bronze industry at Yinxu.

While the focus of this study was upon the identification of the composition of locally produced ceramics, at least two raw materials, granitic rocks and low-silt pastes, were identified as exotic to the Anyang region. There can be no doubt of a nonlocal origin for the igneous rocks because the nearest bedrock sources are some 20 km to the west in the Taihang Mountains, although gravels in streambeds draining the Taihang Mountains might have provided a more proximate source. Acceptance of the nonlocal origin for artifacts made from low-silt pastes is more problematic because of possible sample deficiencies. However, when evaluated in relation to other variables, such as nonlocal rocks/minerals or exotic styles, the case for the nonlocal origin of at least some low-silt artifacts is strengthened. Thus, it is noteworthy that all three of the vessels identified as probably nonlocal (by Jigen Tang) on independent, stylistic grounds before thin-sectioning —two temperless *zun* and one sand-tempered *li* tripod—were later determined to have low-silt pastes (i.e., silt values of 7% or less). In three other instances (involving the funnel and two *li* tripods), low-silt pastes were associated with exotic rock tempers (Fig. 10).

As described by Frederick Matson (1965 : 203): "Ceramic ecology may be considered as one facet of cultural ecology, that which attempts to relate the raw materials and technologies that the local potter has available to the functions in his culture of the products he fashions." This is a worthy, but ambitious objective. To attain it one needs not only knowledge of the composition of local pottery products and the character of locally available raw materials, such as clays, tempers, fuels, etc., but also a great deal of contextual evidence concerning the manufacture, use, and disposal of pottery vessels. While no pretense can be made to having attained this goal in the present study, at least some beginning steps have been taken in that direction.

In our ongoing research we will employ the current data as a baseline to be refined through expanded sediment and artifact sampling, and as a comparative context for evaluation of the local versus exotic status of red wares, glaze wares, and stonewares that also occur in Shang contexts at Anyang. These baseline data, it is hoped, can be employed to intensify the search for and recognition of ceramic production precincts that have so far escaped detection at Anyang.

NOTES

1. Yinxu has been extensively excavated since the first scientific excavations in 1928, producing a vast amount of archaeological and textual data—including oracle bone inscriptions, ritual bronzes, jades, pottery, stone carvings, and monumental architecture, such as palatial foundations, gigantic royal tombs, and chariot burials—rarely if ever matched by any other Early Bronze Age sites in China. There are a number of distinctive areas within the urban settlement, including the "temple-palace complex" as a core near the center, a royal cemetery, workshops, residential compounds, and non-royal cemeteries. In 2006, the site was inscribed on UNESCO's World Heritage List.
2. The research reported herein was conducted in the context of a long-term, multi-disciplinary research project in the Anyang area under the collaborative direction of George (Rip) Rapp, Zhichun Jing, and Jigen Tang.
3. Both loessic and alluvial soils were locally available clay sources for the potters at Huanbei and Yinxu. In the western part of the area, i.e., the upper Huan River valley, the old land surface with which Shang sites are associated is represented by a strong brown paleosol that developed on the aeolian deposit of the early Holocene. At Yinxu, the loessic paleosol is buried 2–3 m beneath the modern floodplain. In contrast, a dark-gray or dark-brown fine-textured alluvial paleosol was found under the modern floodplain in the Lower Huan River valley, east of Yinxu (Fig. 1). The sediment sources for the alluvial paleosol may be the primary loess and/or locally weathered deposits. Based on C-14 dates as well as pedological characteristics, the two paleoeols appear to be contemporary.
4. *Li* tripods are one of the most common pottery vessel forms found at Yinxu, Huanbei, and other Shang sites in China. Multiple lines of evidence indicate that cooking was the main function of these vessels: (1) their distinctive form, with the body elevated on three legs, ideally suits them for placement directly over a heat source; (2) sooting of the exteriors is extremely common, confirming that they had been subjected to heating; and (3) food residues are commonly found on the interiors.

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ABSTRACT

This article describes the results of petrographic analyses of ceramic thin sections from the Shang sites of Huanbei and Yinxu in Anyang, Henan, China. The initial goal was to determine the physical composition of locally produced ceramic artifacts. This was accomplished by focusing upon gray wares, the most common ceramic class in Shang contexts at Anyang, and comparing the findings to local, clay-rich sediments in both qualitative and quantitative terms. The resulting data provide objective bases for distinguishing imported ceramic items, notably those with exotic rock tempers and/or distinctive, low-silt pastes, and for making further inquiries into the role of ceramic production and exchange in the development and functioning of Shang society. The study revealed an unexpected amount of compositional diversity within Shang gray wares and indicates that at least three local sediments and three different technologies were utilized in the manufacture of ceramic objects. For most ceramic objects utilized in daily activities, such as storage and serving vessels and drainpipes, untempered loessic sediments were employed. By contrast, for cooking vessels, alluvial sediments tempered either with sand or grit (crushed rock, some of which was exotic) were normally employed. A third technology, for bronze piece molds, utilized loess, which was untempered, but apparently processed so as to concentrate the silt content thus increasing porosity and minimizing shrinkage, properties that would reduce flaws in cast bronzes. KEYWORDS: ceramic petrography, China, Shang Dynasty, Anyang, Huanbei, Yinxu.